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# Recursive ray acoustics for threedimensional soundspeed profiles

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gives the sound field at any point in the water or sediment of the wedge. This analysis differs from the earlier work of Deane and Tindle (submitted to JASA, 10 December 1991), which is restricted to propagation in a plane perpendicular to the wedge apex. The present work uses a Bessel function expansion that results in a computationally efficient solution to the field which is valid throughout the wedge.

10:30

**4UW10. Recursive ray acoustics for three-dimensional sound-speed profiles.** Lawrence J. Ziomek (Dept. of Elec. and Comput. Eng., Code EC/Zm, Naval Postgraduate School, Monterey, CA 93943)

A recursive ray acoustics (RRA) algorithm for three-dimensional sound-speed profiles is presented. The RRA algorithm is simple, fast, and accurate and uses arc length as the independent variable. It can be used to compute the position, angles of propagation, travel time, and path length along a ray path. The accuracy of the RRA algorithm was tested by comparing its results with those obtained from a ray acoustics algorithm that requires the solution of a system of four, first-order, ordinary differential equations (ODEs). The ODE algorithm, which uses horizontal range as the independent variable, can only handle one-dimensional, depth-dependent, sound-speed profiles (SSPs). Therefore, five standard, depth-dependent, SSPs were used to test the two algorithms. The results from the ODE algorithm were treated as the benchmark, with respect to accuracy, for comparison purposes. The RRA algorithm proved to be very accurate for the test cases tried. After the accuracy of the RRA algorithm was validated by using one-dimensional SSPs, its three-dimensional sound-speed capability was also tested. [Work supported by DARPA and the Naval Postgraduate School Direct Funded Research Program, sponsored by ONR, Code 1125 OA.]

10:45

**4UW11. Acoustic modeling through a Mediterranean water lens (Meddy).** David G. Browning, George Botseas, and Eugene M. Podeszwa (New London Detachment, NUWC—Newport Div., New London, CT 06320)

Mediterranean water lenses (Meddies), as reported by Armi [L. Armi and W. Zenk, J. Phys. Oceanogr. **14**, 1560–1576 (1984)], are small warm-core eddies with a large width (100 km) to thickness (0.9 km) ratio. Centered at a depth of approximately 1000 m, they were observed in the Canary Basin of the North Atlantic Ocean. These are unlike many warm-core eddies that extend to or near the surface [P. A. Nysen, P. Scully-Power, and D. G. Browning, J. Acoust. Soc. Am. **63**, 1381–1388 (1978)], and hence may cause unique propagation anomalies for certain source–receiver configurations. A set of reported oceanographic specifications of a Meddy was converted to sound-speed profiles which were merged with historical data below a depth of 2000 m. Acoustic modeling runs at 200 Hz were made across the Meddy using the IFD/PE model. The results were compared to normal propagation predictions for the area. The characteristic shift of the convergence zones is observed, but as might be expected the impact is relatively small for shallow source–receiver configurations and greatest for source and receiver depths near the center of the Meddy.

11:00

**4UW12. Modal travel time and dispersion with an eddy lens (EL).** E. C. Shang and Y. Y. Wang (CIRES, Univ. of Colorado/NOAA/Wave Propagation Lab., 325 Broadway, Boulder, CO 80303)

A special type of mesoscale eddy, called intrathermocline eddy or eddy lens (EL), has been studied intensively in oceanography over the past decades. The special features of the EL are (1) the deep warm core (near the sound channel axis), (2) the strong anomalies of sound speed (can be as large as 10–15 m/s), and (3) the long lifetime. The significant impact on acoustic wave propagation of EL due to these features is the "double channel" effect. In this paper, mode couplings caused by the "double channel" induced by EL is investigated. For ocean acoustic tomographic interest, modal travel time and modal dispersion are calculated by using the modal spectrum of the PE field (MOSPEF) method. Numerical simulation for a 57-Hz pulse with 10-Hz bandwidth is conducted. [Work supported by NOAA.]

11:15

**4UW13. On equations for the speed of sound in seawater.** Brian D. Dushaw, Peter F. Worcester, Bruce D. Cornuelle (Scripps Inst. of Oceanography, Univ. of California, San Diego, La Jolla, CA 92093-0208), and Bruce M. Howe (Appl. Phys. Lab., Univ. of Washington, Seattle, WA)

Long-range acoustic transmissions made in conjunction with extensive environmental measurements and accurate mooring position determinations have been used to test the accuracy of equations used to calculate sound speed from pressure, temperature, and salinity. The sound-speed field computed using the Del Grosso equation [V. A. Del Grosso, J. Acoust. Soc. Am. **56**, 1084–1091 (1974)] give predictions of acoustic arrival patterns which agree significantly better with the long-range measurements than those computed using the Chen and Millero equation [C. Chen and F. J. Millero, J. Acoust. Soc. Am. **62**, 1129–1135 (1977)]. The predicted ray travel times and travel time error have been calculated using objectively mapped sound-speed fields computed from CTD and XBT data. Using the measured and predicted ray travel times, a negligible correction to Del Grosso's equation of $0.05 \pm 0.05$ m/s at 4000-m depth is calculated. Small errors of about 50 m in the GPS determination of mooring positions lends a depth-independent error of 0.1 m/s to the sound-speed equation correction. [Work supported by NSF and ONR.]